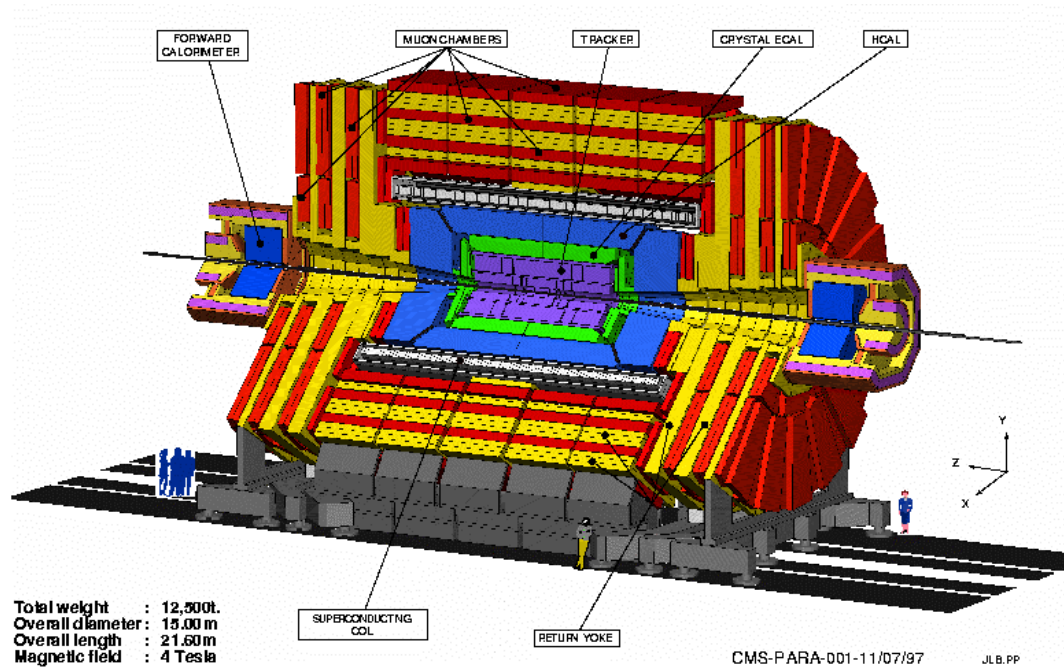


U.S. Operations Management Plan for the CMS Detector



August 2004 – Revision 6.4

Submission and Approvals

This Management Plan defines the plans, organization, systems and relevant interfaces for the U.S. Collaboration's Pre-Operations and Operations (including detector maintenance, henceforth referred to collectively as "M&O") for the CMS detector at the Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN). The U.S. role in the operation of the CMS detector is funded jointly by the U.S. Department of Energy and the National Science Foundation. This document is intended to meet the expectation for a management plan addressing pre-operations & operations discussed in Appendix 1 and Ref. 2 (DOE/NSF MoU and FNAL Host Lab Letter). It will be appended to a broader U.S. CMS Research Program Management Plan that will also incorporate a U.S. CMS Software & Computing (S&C) management plan. The U.S. CMS Research Program Management Plan will be submitted for approval by the U.S. LHC Joint Oversight Group (JOG).

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1 INTRODUCTION

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) are supporting the U.S. CMS Collaboration's involvement in high-energy physics (HEP) research in the two large detectors for the CERN Large Hadron Collider (LHC), ATLAS and CMS, through the participation in detector operations, data monitoring, and the maintenance of equipment for those detectors.

The U.S. CMS Collaboration presently consists of over 380 scientists and engineers from 38 U.S. universities and one national laboratory, and is part of the international CMS Collaboration that has overall operational responsibility for the CMS detector. At the request of the DOE and NSF, the Host Laboratory for the U.S. Collaboration is the Fermi National Accelerator Laboratory (FNAL), in Batavia, Illinois. Fermilab is a DOE Laboratory operated under contract DE-AC02-76-CH-03000 by Universities Research Association, Inc. (URA).

Since U.S. CMS Operations is funded by both DOE and NSF, a Joint Oversight Group (JOG) has been formed by the two agencies to perform periodic reviews and assess performance during the operational phase of CMS. DOE and NSF have requested (via the JOG) that Fermilab act as the Host Laboratory and assume management oversight of the U.S. CMS Operations, which is described in Appendix 1.

1.1 SCOPE OF THE OPERATIONS MANAGEMENT PLAN

The Operations Management Plan (OMP), described herein, defines the management, organization, systems and processes employed to manage the contribution and participation of the U.S. CMS Collaboration in the pre-operations and operations phases of the CMS Detector. This includes control of all technical, cost, and schedule objectives of U.S. CMS Operations, the management structure of U.S. CMS Operations, and the relationship between the DOE/NSF and the Host Laboratory.

This OMP does not cover any effort related to the U.S. CMS Software & Computing (S&C) Program, a parallel U.S. CMS endeavor designed to develop the software and computing resources necessary to enable U.S. physicists to fully participate in the CMS physics program. Furthermore, this OMP does not cover any effort in regard to HEP research scientists or post-docs, as it is assumed that the direction and salaries of scientific personnel for U.S. CMS will be provided via the university and Fermilab base program.

This OMP will be reviewed and revised, as required, to reflect new developments or other agreements among the participants. Revisions will be endorsed by the U.S. CMS Operations Program Manager (OPM), the U.S. CMS Research Program Manager (RPM), Deputy Research Program Manager (DRPM), the Director and Deputy Director of Fermilab, U.S. LHC Program Manager, the Manager of the Fermi Area Office for the DOE Chicago Operations Office, the Program Manager and Associate Program Manager for the U.S. LHC Program, and jointly approved by the Director of the DOE Division of High Energy Physics and the Executive Officer of NSF Physics Division. To the extent that there are inconsistencies or conflicts between this plan and the terms and conditions of applicable laws, regulations, existing contracts, and relevant Memoranda of Agreement, the provisions of those documents shall prevail over this plan.

1.2 RELATED AGREEMENTS AND ORGANIZATIONS

U.S. responsibilities for pre-operation and operations of the CMS Detector are set forth in international agreements and memoranda of understanding. The International Co-operations Agreement Concerning Scientific and Technical Co-operation on Large Hadron Collider Activities of December 8, 1997, defines the U.S. responsibilities common to all parts of the LHC Program. The Experiments Protocol Concerning Scientific and Technical Cooperation on the Large Hadron Collider ATLAS and CMS Detectors of December 19, 1997, describes DOE and NSF responsibilities for the detectors. Finally, there are Memoranda of Understanding between institutions participating in the LHC experiments and CERN, describing the responsibilities of all participants in these experiments. The CMS Memorandum of Understanding between CERN and the CMS institutes governing pre-operations and operations of the experiment clarifies the roles, responsibilities and obligations of the U.S. CMS institutions during the commissioning and operations phases of the experiment.

CERN, in its role as the Host Laboratory for the CMS Detector and LHC Research, is represented by the Chief Scientific Officer, acting on behalf of the Director-General, and agrees to provide the following to the CMS Collaboration for the duration of the experiment;

- Particle beams and related shielding, monitoring equipment and standard communication with the accelerator control rooms;
- Primary beam time allocation and test beam time for testing prototypes and calibrating final detector elements;
- Floor space in the experimental areas for the CMS detector, its auxiliary equipment and the counting and control rooms;

- Laboratory and hall space for construction, testing and assembly of equipment;
- Storage space for spare parts, handling and assembly tools, detector and auxiliary equipment awaiting installation or removal;
- Office space, equipped with standard furniture and infrastructure facilities like terminal lines, telephones, electricity;
- Assistance with the installation and removal of the detector and its auxiliary equipment, including the provision of the crane and rigging services, geometrical survey and alignment, transport of equipment on and between the Laboratory sites, as well as inside the experimental areas;
- Basic infrastructure, such as counting houses, local air conditioning and cryogenics in amounts specified in the MOU;
- Resources needed to operate and maintain the infrastructure and other equipment supplied by CERN as host.
- Computing resources will be the subject of distinct MOU, which are now being formulated.

2 CMS OBJECTIVES

2.1 SCIENTIFIC OBJECTIVES

A fundamental unanswered problem of elementary particle physics relates to the understanding of the mechanism that generates the masses of the W and Z gauge bosons and of quarks and leptons. To attack this problem, we require an experiment that can produce a large rate of particle collisions of very high energy. The LHC will collide protons against protons every 25 ns with a center-of-mass energy of 14 TeV and a design luminosity of $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. It will most likely require a few years after turn-on to achieve full design luminosity of the LHC.

The US CMS Collaboration participates in the operation of the Compact Muon Solenoid (CMS) experiment, designed to study the collisions of protons on protons at a center of mass energy of 14 TeV at the Large Hadron Collider (LHC) at CERN. To enable studies of rare phenomena at the TeV scale, the LHC is designed to operate at a luminosity of $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. The physics program includes the study of electroweak symmetry breaking, investigation of the properties of the top quark, searches for new heavy gauge bosons, probing quark and lepton substructure, looking for supersymmetry, and exploring for other new phenomena.

The detector was designed to fully utilize the high luminosity so that detailed studies of rare phenomena can be carried out. While the primary goal of the experiment is to determine the mechanism of electroweak symmetry breaking via the detection of Higgs bosons, the new energy regime will also offer new opportunities. The detector was designed to be sufficiently versatile to detect and identify the final state products from a great variety of processes. In particular, it is capable of reconstructing the momenta and directions of quarks and gluons (hadronic jets, tagged by their flavors where possible), taus, photons, electrons, and muons and is sensitive to energy carried off by weakly interacting particles such as neutrinos that cannot be directly detected.

2.2 TECHNICAL OBJECTIVES

The CMS detector is designed to perform a comprehensive study of the source of electroweak symmetry breaking. It is expected to operate for twenty or more years, with appropriate upgrades, at the CERN LHC, observing collisions of protons, and recording more than 10^9 events per year. The critical objectives to achieve these goals are:

- Excellent muon identification capability and momentum resolution.

- Efficient tagging of b-decays and τ -jets.
- Excellent photon and electron identification capability, as well as energy and directional resolution.
- Hermetic calorimetry coverage to allow accurate measurement of direction and magnitude of energy flow, and excellent reconstruction of missing transverse momentum.
- Efficient charged particle track reconstruction and good momentum resolution.
- Well-understood trigger and data acquisition systems to go from 1 GHz raw interaction rate to ~ 100 Hz readout rate without significant loss of interesting signals.

2.3 FISCAL AND RESOURCE OBJECTIVES

The method for determining the costs, resources, and scope of the CMS Collaboration for pre-operations and operations of CMS is derived from negotiations between the Collaboration, CERN, and the respective funding agencies via the Resource Review Board. This agreement is defined in the MOU between CERN and the Collaborating Institutes. It is assumed that each particular institution's fiscal responsibilities are determined independently based upon guidance from their respective funding agencies.

The U.S. CMS Collaboration will establish annual budget requests to the DOE and NSF based upon CMS equipment and manpower estimates, and distribute the management reserve as necessary to effectively maintain the U. S. role in CMS. The U.S. Operations Office will also act as a liaison to the CMS Management for the pre-operations and operations of CMS.

2.4 SCHEDULE OBJECTIVES

Pre-operations for the CMS collaboration started in FY01, with funds allocated for cranes and crane maintenance, magnet power supplies, test beam and survey operations, support for safety systems, offline computing, and general operations support. Pre-operations support for U.S. CMS commenced in FY02, with planned expenditures to its Category A contribution (personnel, utilities, cooling, gas and cryogen systems for SX-5 magnet test), CERN branch office, travel, and education outreach.

The period of FY03-FY05 will see the U.S. CMS construction project ramp down its project office and subsystem engineering and technical staffs, with an increased presence of physicists and post-docs at CERN for the CMS commissioning. CERN team account activities are expected to significantly increase requiring a ramping-up of the U.S. CMS Operations

Office, both at Fermilab and CERN. Operational start-up costs for subsystem expenditures, such as operations personnel, utilities, data acquisition and computer system support began in FY03. First collisions at the LHC are scheduled for FY07, with the first data run presently scheduled for late in calendar year 2007.

3 CMS ORGANIZATION

3.1 THE INTERNATIONAL CMS EXPERIMENT AND ITS MANAGEMENT

The large general-purpose LHC experiments rank among the most ambitious and challenging technical undertakings ever proposed by the international scientific community. The inter-regional collaborations assembled to design, implement and execute these experiments face unprecedented sociological challenges in efficiently managing their enormous, yet highly decentralized, human and economic resources. The CMS approach to this challenge is to base most of the CMS governance on the collaborating institutions rather than on any national blocks. Thus the principal organizational entity in CMS is the Collaboration Board (CB), which typically consists of one voting representative from each collaborating institution.

The CB is the entity within CMS that must ratify all policy and technical decisions, and all appointments to official CMS positions. It is chaired by an elected Chairperson who serves for a non-renewable two-year term. The Deputy Chairperson, elected in the middle of the Chairperson's term, succeeds the Chairperson at the end of his/her term.

Executive responsibility within CMS is carried by the Spokesperson who is elected by the CB to a renewable three-year term. The Spokesperson is empowered to nominate a Deputy Spokesperson who will assist the Spokesperson in carrying out his/her duties. The Spokesperson represents the CMS Collaboration before all relevant bodies, and carries the overall responsibility for the CMS Detector Project.

During the construction phase, the CMS central management team has relied heavily on the Technical and Resource Coordinators, both CERN staff members whose appointments to their roles require CERN management approval. It is anticipated that these roles will continue in a similar fashion during the operational phase of CMS. The Technical Coordinator has the overall responsibility for the technical aspects of the detector construction. This includes responsibility for the integration of the CMS subsystems and for coordinating the CERN infrastructure, including the installation of the experiment in the surface and underground areas. The Resource Coordinator is responsible for budget and manpower planning, including securing the Common Projects resources, and for negotiating the MOU's with the various funding agencies.

The CMS Spokesperson chairs a Steering Committee (SC), consisting of high-level representatives of all major detector subsystems plus the Technical and Resource Coordinators.

This committee acts as an effective and timely decision-making body, which develops solutions to relevant technical, resource, and/or integrations problems. A larger body, the Management Board (MB) meets during the quarterly CMS Weeks, and acts as a liaison body between the SC and members of the CB.

For pre-operations and operations activities, decisions by the CMS Steering Committee (SC) will be adopted directly or, if not compatible with U.S. operating procedures, adapted so as to match the SC decision as closely as possible. In the latter case CMS management will be consulted and informed about the detailed U.S. implementation.

3.2 THE RESOURCE REVIEW BOARD (RRB)

The RRB meets twice per year, usually in April and October, and is comprised of representatives from all CMS funding agencies and the managements of CERN and CMS. The U.S. has DOE and NSF representatives on the RRB. The role of the RRB includes:

- Reaching agreement on the CMS Memoranda of Understanding.
- Monitoring Common Operations and the use of the Common Funds.
- Monitoring the general financial and manpower support.
- Reaching agreement on pre-operation and operation procedures and monitoring their functions.
- Endorsing the annual pre-operation and operation budgets of the detector.

With regard to oversight of the CMS M&O costs, the RRB will be assisted by a Scrutiny Group, the role of which is to analyze critically the M&O reports and estimates made by the Collaboration, refine estimates in consultation with the Collaboration and advise the RRB on the course of action to take. The Scrutiny Group is set-up to include representatives from Member States and Non-Member states, including a U.S. representative.

4 DEPARTMENT OF ENERGY (DOE) AND NATIONAL SCIENCE FOUNDATION (NSF)

The Department of Energy (DOE) and the National Science Foundation (NSF) are the funding agencies for the U.S. participation in U.S. CMS pre-operations and operations. As such the agencies determine the program scope, approve annual budgets, and monitor program implementation. The organization structure of DOE and NSF as it relates to the U.S. CMS pre-operations and operations is shown in Appendix 2.

The DOE has delegated responsibility for the U.S. CMS activities to the Office of Science, Office of High Energy Physics. The NSF has delegated responsibility for the U.S. CMS activities to the Division of Physics, Elementary Particle Physics Programs.

U.S. CMS Operations receive substantial support from both DOE and NSF. Almost all the subsystems involve close collaboration between DOE and NSF supported groups. It is therefore essential that DOE and NSF oversight be closely coordinated. The DOE and NSF have established a U.S. LHC Joint Oversight Group (JOG) as the highest level of joint U.S. LHC Program management oversight. The JOG has responsibility to see that the U.S. LHC Program is effectively managed and executed so as to meet the commitments made to CERN under the International Agreement and its Protocols. The JOG provides programmatic guidance and direction for the U.S. LHC Research Program and coordinates DOE and NSF policy and procedures with respect to both. The JOG approves and oversees implementation of the U.S. LHC Program and individual Management Plans associated with the U.S. LHC Research Program, including this U.S. CMS Operations Management Plan.

All documents approved by JOG are subject to the rules and practices of each agency and the signed Agreements and Protocols.

The U.S. LHC Program Office is established to carry out the management functions set forth in the MOU, the U.S. LHC Construction Project Execution Plan, and the Management Plans associated with the U.S. LHC Research Program. The program office is staffed by Federal employees or IPA appointees assigned by the DOE and NSF. As the DOE has been designated “lead agency” for the U.S. LHC Program, the U.S. LHC Program Manager that heads the program office will generally be a DOE employee. The Associate U.S. LHC Program Manager will generally be an NSF employee. Additional information on the role of the U.S. LHC JOG and U.S. LHC Program Office is provided in the U.S. CMS Research Program Management Plan.

5 U.S. CMS ORGANIZATION

5.1 INTRODUCTION

The management structure of the U.S. CMS Research Program, specifically the RPM and DRPM offices, were defined in a letter from JOG to the Fermilab Director dated November 7, 2003. An organization chart for the U.S. CMS Research Program is presented in Appendix 4. U.S. CMS Operations functions within the context of the internationally funded CMS experiment located at CERN. The general responsibilities of the U.S. participants are described in the pre-operations and operations MOU between CERN and the CMS Collaborating Institutes. In essence, the CMS Collaboration has responsibilities for R&D studies, upgrade designs, and normal maintenance and operation of detector systems and components as agreed to and described in the MOU, and their addenda.

The U.S. CMS Operations effort is managed by the U.S.CMS Operations Office, located at the Fermi National Accelerator Laboratory (FNAL), under the direction of the appointed U.S. CMS Operations Program Manager (OPM). The OPM position was defined in a letter from Fermilab to JOG dated January 26, 2004 (in which the OPM is referred to as the M&O Program Manager). The Operations Program Manager has the principal authority for day-to-day management and administration of all U.S. CMS operations activities and funding. The U.S. CMS Research Program Manager is responsible for management oversight of the U.S. CMS Operations, and DOE and NSF jointly provide requirements, objectives and funding.

5.2 MEMBERSHIP OF THE U.S. CMS COLLABORATION

The U.S. CMS Collaboration consists of physicists and engineers from all U.S. institutions collaborating on the CMS experiment at the CERN LHC. Appendix 3 contains a list of the participating U.S. institutions for pre-operations and operations of the CMS detector. Individuals from these institutions share responsibility for the operations and execution of the experiment with collaborators from the international high-energy physics community outside the U.S.

5.3 THE U.S. CMS OPERATIONS MANAGEMENT

To facilitate interactions with the U.S. funding agencies and for effective management of U.S. CMS activities and resources, an operations management structure has been established within the Operations Office located at FNAL. The operations management is a component of the U.S. CMS Research Program which also includes the software and computing program. An organization chart for U.S. CMS Operations is presented in Appendix 5. This organization is headed by a U.S. CMS Operations Manager and supported by an Operations Office along with U.S. Subsystem Managers for each of the major detector elements in which the U.S. is involved.

The organization also includes a Collaboration Board (CB) with representation from each collaborating institution, and a U.S. CMS Collaboration Advisory Board (AB). The responsibilities of each will be described below. The U.S. CMS planning and management for pre-operations and operations are done in close cooperation with the overall CMS management. The U.S. Subsystem Managers interact closely with the corresponding overall CMS Subsystem Operations Managers, and the U.S. CMS Operations Program Manager maintains close contact with the CMS Spokesperson, and the Technical and Resource Coordinators.

5.3.1 *Operations Manager*

The U.S. CMS Operations Program Manager (OPM) has the responsibility of providing programmatic coordination and management for the U.S. CMS Operations of CMS. He/she represents U.S. CMS Operations in interactions with overall CMS management, CERN, DOE, NSF, the universities and the Host Laboratory (FNAL). The OPM is appointed by the U.S. CMS Research Program Manager with concurrence of the U.S. CMS Deputy RPM, and Fermilab, upon recommendation from the U.S. CMS Collaboration. He/she reports to the U.S. CMS Research Program Manager and will be advised by the AB.

The management responsibilities of the U.S. CMS Operations Manager include:

- Appointing, after consultation with the Collaboration, the RPM and DRPM, the U.S. Subsystem Managers (SMs) responsible for coordination and management within each detector subsystem.
- Recommending to the RPM and DRPM the institution-by-institution funding allocations for adequate incremental base support for U.S. CMS operational efforts. These recommendations will be made with the advice of the SMs, and the U.S. CMS Collaboration Board, through consultation with the subsystem Institutional Board (IB).
- Approving budgets and allocating funds in consultation with the SMs and managing the management reserve budget.

- Establishing, with the support of the RPM and DRPM, a U.S. CMS Operations Office with appropriate support services.
- Working with the RPM to set up and respond to whatever advisory or other mechanisms the RPM feels necessary to carry out his/her oversight responsibility.
- Keeping the RPM well informed on the progress of the U.S. CMS operations effort, and reporting promptly any problems whose solutions may benefit from the joint efforts of the U.S. CMS Operations Manager and the RPM and DRPM.
- Negotiating and signing the U.S. Institutional MOUs representing agreements between the U.S. CMS Operations Office and the U.S. CMS collaborating institutions specifying the M&O responsibilities to be provided and the resources available on an institution-by-institution basis.
- Periodically reporting on CMS operational status and issues to the RPM and DRPM.
- Ensuring that ES&H and QA/QC activities are managed effectively.

DOE funding will be a mixture of grants and Research Contracts through FNAL. NSF funding from FY04 will be through subcontracts through UCLA. Further details on the identities and roles of the various participants in the U.S. CMS Collaboration governance are given below.

5.3.2 Organization of the Operations Office

The U.S. CMS Operations Office is based at the Host Laboratory, Fermi National Accelerator Laboratory, in Batavia, IL. The Operations Office provides technical coordination, financial and program management support to the Operations Manager. Operations of the U.S. CMS Operations Office include:

- Preparing the yearly funding requests to DOE and NSF for the anticipated U.S. CMS pre-operations and operations activities. Any approved or proposed upgrade R&D efforts may also be included in these yearly funding requests.
- Assisting in overall CMS detector integration and operation.
- Coordinating and generating the quarterly report.
- Maintaining an audit trail for all actual costs incurred by the Operations Office and U.S. CMS Operations.
- Developing and maintaining the integrity of the budget baseline, management reserve, and change request (CR) logs.
- Maintaining the current cost, schedule, and dictionary, and records of all changes to the M&O plan.

- Establishing the annual funding requirements for each Institution.
- Providing the necessary labor resources to assure the efficient operation of the Operations Office.
- Executing all labor, material and travel purchase actions initiated by the Operations Office.

CERN Branch Office

A branch office of the U.S. CMS Operations Office is located at CERN to facilitate the pre-operations and operations activities of U.S. CMS, and to improve the coordination and communication between the CMS Collaboration and the U.S. CMS collaborating institutes. The duties and responsibilities for the CERN branch office are:

- Monitor activities on the U.S. CMS L2 Team Accounts (used by U.S. groups to make purchases through CERN), and act as a liaison for U.S. CMS operations with CERN accounting. L2 Team accounts are used to authorize expenditures at CERN related to U.S. CMS operations. A Team Account will also be used for disbursement of U.S. funds for Category A costs (common expenditures levied upon the CMS collaboration) related to CMS pre-operation and operation expenditures.
- Expedite travel, computing support, shipping requests from U.S. CMS users at CERN and act as a liaison to U.S. visitors for CMS detector operations.

5.3.3 Subsystem Managers

The Subsystem Managers are responsible for the operational, technical, and cost aspects of their subsystems. They develop the budgets for the institutions participating in their subsystems. They are appointed by the U.S. CMS Operations Manager upon recommendation of the IB members whose institutions are involved in that subsystem and the RPM and DRPM.

5.3.4 Collaboration Board

The U.S. CMS Collaboration acts through a Collaboration Board (CB), consisting of one member from each collaborating institution and a Chair elected by the CB, to address policy issues affecting the U.S. CMS Collaboration. The Chair serves for a two-year renewable term.

The CB members represent the interests of their institutions and serve as points of contact between the U.S. CMS management structure and the collaborators from their institutions. They are selected by the CMS participants from their respective institutions.

5.3.5 *Advisory Board*

The purpose of the U.S. CMS Advisory Board is to facilitate the participation of U.S. physicists in the CMS experiment, and to consider any policy issues brought to the U.S. CMS Collaboration Board. The Advisory Board has the following membership:

- U.S. Collaboration Board Chair
- U.S. Collaboration Board Deputy Chair
- U.S. CMS Subsystem IB Chairs
- U.S. CMS Education/Outreach Coordinator
- U.S. CMS Physics Coordinator
- Additional members as deemed appropriate by the U.S. CMS CB Chair

The Subsystem IB Chairs are elected for two-year renewable terms by the IB members whose institutions are associated with the given subsystem.

The Education/Outreach Coordinator, elected for a two-year renewable term by the full CB, is expected to actively promote educational programs associated with CMS and with the U.S. member institutions, and to report to the Advisory Board on these issues. He/she will also act as liaison to DOE and NSF for educational activities.

The Physics Coordinator, elected for a two-year renewable term by the full CB, is expected to actively promote physics programs, conferences, and publications, associated with CMS and with the U.S. member institutions, and to report to the Advisory Board on these issues.

5.4 U.S. CMS RESEARCH PROGRAM MANAGER

Fermilab appoints the U.S. CMS Research Program Manager for overall line management responsibility for the U.S. CMS Research Program, which includes U.S. CMS Software and Computing, Maintenance and Operations, and Research and Development for possible future detector improvements.

The U.S. CMS Research Program Manager is a member of the U.S. CMS. He/she interacts with the host laboratory, international CMS and the US funding agencies to identify and represent the needs for the entire U.S. CMS Research Program and provides the input required to optimize the program within the available funding, once it is known.

The U.S. CMS Research Program Manager will act to optimize the full U.S. CMS Research Program, taking into account the line organization and planned schedule of work for U.S. CMS Software and Computing and Detector Maintenance and Operations.

The U.S. CMS Deputy Research Program Manager (DRPM) is appointed by Fermilab. The DRPM will be the principal investigator for the NSF funds supplied for the support of the U.S. CMS RP. The DRPM is also the main point of contact between the U.S. CMS RP and the DOE and NSF base programs.

5.5 FERMION NATIONAL ACCELERATOR LABORATORY (FNAL)

The DOE and NSF have assigned FNAL management oversight responsibility for U.S. CMS. The FNAL Director has the responsibility to assure that the U.S. CMS Research Program efforts are being soundly managed, that activities are proceeding in a timely manner, that technical or financial problems, if any, are being identified and properly addressed, and that an adequate management organization is in place and functioning. The FNAL Director has delegated certain responsibilities and authorities to the Deputy Laboratory Director (DLD). The DLD is responsible for day-to-day management oversight of the U.S. CMS RP and the U.S. CMS RPM reports to him. Specific responsibilities of the FNAL Directorate include:

- Acting on recommendations of the U.S. CMS Collaboration, appoint the U.S. CMS RPM and DRPM, subject to the concurrence of the Joint Oversight Group.
- Establish an advisory structure external to the U.S. CMS Operations Office for the purpose of monitoring both management and technical progress for all U.S. CMS operations.
- Ensure that the RPM and OPM have adequate staff and support, and that U.S. CMS management systems are matched to the pre-operation and operation needs of U.S. CMS.
- Consult regularly with the RPM to assure timely resolution of management challenges.
- Concur with the CMS/CERN Memorandum of Understanding specifying the U.S. role and obligation in CMS pre-operations and operations.
- Concur with the institutional Memoranda of Understanding for the U.S. CMS collaborating institutions that specify the role and responsibility during CMS pre-operations and operations for each institution.
- Ensure that accurate and complete reporting to the DOE and NSF is provided in a timely manner.

- Review U.S. CMS Operations with regards to yearly budget requests and the effectiveness of management reserve funds used to address problems during the fiscal year cycle.

FNAL, in addition to management oversight, has also taken on the role of Host Laboratory for the U.S. CMS Collaboration, which assumes leadership responsibility for the following;

- Financial reporting and tracking support to the U.S. CMS Collaboration through its internal fiscal and management systems.
- Establish an environment at FNAL including a remote control room and LHC Physics Center to facilitate U.S.-based research.
- Establish a Tier 1 site at FNAL for the U.S. Software & Computing effort.

The NSF Division of Physics has delegated financial accountability to UCLA, inclusive of line management authority, responsibility and accountability for overall program implementation, and contract administration. The principal investigator of UCLA is responsible for dispersal of all NSF funds according to the allocations recommended by the U.S. CMS RPM and consistent with NSF policies with the advice of the DRPM.

Operations Management Group

An Operations Management Group (OMG), analogous to the Project Management Group presently in place for the construction phase, may be organized by the Fermilab Deputy Director and report to FNAL management. The role of the OMG in CMS detector operations is to provide oversight of the work performed by U.S. institutions and advise Laboratory management on the rate of progress in and adherence to the operations plan as it relates to operational, technical, and cost performance. Additional mechanisms may be employed as deemed necessary to exercise the oversight function. These may include special reviews or meetings and attendance at Department of Energy/National Science Foundation (DOE/NSF) reviews of U.S. CMS Operations.

The U.S. CMS OPM will control changes in requirements, costs and schedule, in consultation and agreement, as appropriate, with the OMG, the RPM and the DRPM.

Change control is established in three areas, technical changes, schedule changes, and cost changes. Change requests will be submitted to the Fermilab U.S. CMS Operations Management Group and the U.S. CMS Research Program Manager will consider and approve or disapprove all change requests.

The Program Office will maintain a log of such approved change requests at any level. This log will be available for review by all management in full transparency. All cost changes to the baseline costs shall be traceable. The OPM must approve in advance all procurements requiring the use of management reserve.

5.6 MEETINGS WITH DOE AND NSF

In addition to the annual budget proposals, there are regular coordination meetings between the DOE/NSF Project Manager, the Joint Oversight Group, the DLD, and U.S. CMS operations management personnel for problem identification, discussion of issues, and development of solutions. Written quarterly reports on the status of the U.S. CMS Operations are submitted regularly from the U.S. Operations Office. Typical recipients of this report are the DOE/NSF Program/Project Staff, the FNAL DLD, the OMG, and U.S. CMS CB.

5.7 PERIODIC REVIEWS

Peer reviews, both internal and external to the Collaboration, provide a critical perspective and important means of validating designs, plans, concepts, and progress and will be employed when requested by the U.S. CMS Operations Manager. The DOE and NSF may conduct their own reviews of U.S. CMS pre-operations and operations activities and plans. In addition, the OMG may set up internal review committees to provide technical assessments of various U.S. CMS activities, as the DLD considers appropriate. Normally, review reports are made available to members of the U.S. CMS Collaboration.

In addition to the day-to-day interaction of the line managers there are major mechanisms for periodic formal assessment of the U.S. CMS Research Program. These mechanisms for assessment include meetings of the JOG, annual or periodic peer-reviews and evaluations conducted at the request of the JOG, U.S. LHC Program Office reviews, host/lead laboratory oversight activities, and internal reviews conducted by the laboratory and university program managers.

In particular, regular reviews will be conducted for both the U.S. LHC Detector Maintenance & Operations (M&O) and the U.S. LHC Software & Computing (S&C) elements. A U.S. LHC Detector M&O Evaluation Group (MEG) has been established including DOE/NSF representatives, with members having expertise in maintenance and operation of particle physics detectors (see reference 6). The MEG will annually assess the U.S. CMS Collaborations'

proposals concerning the M&O scope and costs and report to the JOG. Similarly, the S&C efforts of U.S. CMS will be reviewed annually by a full committee of computing experts, augmented by smaller semi-annual reviews.

6 WORK BREAKDOWN STRUCTURE

The scope of M&O was defined in a letter of March 7, 2002 from JOG. For example, upgrades were declared not to be part of M&O. All work required for U.S. CMS Operations is organized into a Work Breakdown Structure (WBS). The WBS completely defines the scope of pre-operations and operations support for U.S. CMS, and is the basis for planning, cost estimates, and performance measurement.

Appendix 6 shows an overview of the WBS structure, which includes individual subsystems and other support functions such as Common Operations, Operations Management, and Upgrade R&D. The WBS has been expanded to a level sufficient to allow definition of individual tasks/elements for which cost can be reasonably estimated and tracked during the operations phase of CMS. Each individual subsystem has a unique WBS structure no lower than WBS Levels 6, which serve to define their pre-operations and operational efforts on the specific subsystem. Management Reserve, and R&D for Detector Upgrades (including prototyping for Upgrades) have been broken out separately in order to distinguish these costs from the conventional costs related to pre-operations and operations.

WBS Outline Structure

The levels of the work breakdown structure reflect the logical breakdown of the work required to complete the program. Lower levels provide greater detail. The number of levels is established by extending the description down to a level at which individual components can be identified and associated into a well-defined piece of equipment or task.

The detailed activities to operate the US CMS responsibilities in CMS are described in the work breakdown structure dictionary. Each element of the work breakdown structure has cost, manpower, and schedule associated with it and is the key element for planning and controlling cost and schedule. The resources attached to each task represent, as far as is possible, all the needed resources whether they are funded by the RP or from other sources.

Changes to parameters are controlled by a change control system. The impact of any such change on the associated cost, schedule, and WBS dictionary will be evaluated by the appropriate Change Control Board, the OMG. All changes must be approved at the appropriate level before implementation. Once approved, the changes will be incorporated in the work breakdown structure, work breakdown structure dictionary, baseline budget, estimate to complete, schedule, etc. as required.

6.1 COST ESTIMATING

The work breakdown structure supports a systematic approach to preparing the cost estimate for the program. The work breakdown structure is extended to a sufficient level of detail to allow definition of individual components for which a cost can be reasonably estimated. The budget and cost estimate are equal for the lowest level in each branch of the work breakdown structure at any time.

The total estimated cost plus management reserve for U.S. CMS detector operations from FY02 through FY08 is presented in Appendix 7. All estimates are in actual-year dollars and include all fully encumbered labor and material costs required to complete the work for U.S. CMS. The common operational support (WBS 18) is specified to represent roughly 22% (pro rata) of the total CMS pre-operations and operations, so called Category A costs, as measured in Swiss-Franc CERN accounting.

The cost estimate has been prepared using input provided by each Subsystem Manager. U.S. CMS Institutions responsible for a given L2 WBS category can be found in Appendix 8.

To take into account uncertainties in the cost and effort estimates, avoid the risk of overruns, and allow the Operations Office a quick response mechanism to resolve problems in an early phase, a management reserve of roughly one quarter of the annual base cost estimate will be held in the Operations Office. The use of this management reserve, WBS 21, will be reviewed annually by the Research Program Manager and the Fermilab Deputy Director to maximize the effectiveness of reserve funds for problem solving during the fiscal year cycle.

6.2 SCHEDULING

The work breakdown structure also supports a systematic approach to preparing the program schedule. Again, each work breakdown structure element at the lowest level of the structure is assigned a duration. Establishing the interdependencies between the various elements creates the program schedule.

A derived set of milestones is part of the resource loaded schedule. That schedule is synchronized to the master CMS schedule, presently version 34 (v34). The resulting high level milestones for the RP are shown in Appendix 9. They are reported in the quarterly operations report.

6.3 BUDGETING

The schedule is “resource loaded” by spreading the cost estimate over time to reflect the work plan. This provides each element of the work breakdown structure at the lowest level a budgeted “cost of work scheduled”. The budget of the program can be seen at any level by performing a summary over contributing lower level.

Note:

- The budget reflects the US CMS financial plan, which represents the goals of the operations management plan.
- The budget is expressed in time-phased quantifiable or measurable terms so that status along the way can be determined.
- All Level 2 components of the organization will be made aware of their portion of the overall budget.
- Performance against the budgets will be monitored and reviewed by the WBS L2 Manager, the US CMS Operations Manager, the RPM, and the DRPM.

6.4 WORK BREAKDOWN STRUCTURE SUPPORT REQUIREMENTS AND DICTIONARY

The work breakdown structure, in conjunction with the associated resource-loaded schedule provides the framework for projecting funding and manpower requirements in time. WBS Level 2 Managers are required to provide the OPM a detailed work breakdown structure dictionary of their subsystems. This dictionary and the basis of estimate provide the documentation, which defines the quality of the estimated costs.

6.5 PERFORMANCE MEASUREMENT

The work breakdown structure supports the monitoring, control, and reporting of cost performance. Since each element of the work breakdown structure, and by association each work element, has a well-defined budget and schedule, a view of the progress of the program at any level is available at any time. Comparison of the actual costs (“actual costs of work performed”) of invoices received and planned budget affords the management a cost comparison.

6.6 THE USE OF MANAGEMENT RESERVE

The funds for the management reserve are estimated in WBS 21 and will be allocated annually once the available RP funds for a given FY are determined. They are held in the

Operations Office, with requests for these funds entertained upon receipt of a proposal by a L2 subsystem manager. If applicable, the Operations Manager, will consult with the RPM and DRPM and thence with the CMS Steering Committee on the setting of scientific priorities within CMS, prior to releasing reserves.

6.7 UPGRADE R&D

The funds for upgrades are estimated in WBS 20. It is expected that decisions on priorities for upgrades will be set by CMS, and that actual upgrade activities will be based upon proposals based upon scientific merit and available CMS funding. Approved R&D or upgrade funding for a given L2 subsystem will be authorized by the Operations Manager upon receipt and review of the L2 R&D plan for a specific upgrade.

7 MANAGEMENT SYSTEMS

The U.S. CMS Operations Management System incorporates two major features; (1) Operational Support Development, which entails establishing the necessary cost and schedule baselines, management reserves, and work execution plans to meet the planned goals, and (2) and Operations Performance, which consists of monitoring, reporting, and analyzing the U.S. CMS operational performance.

7.1 OPERATIONAL SUPPORT DEVELOPMENT

The cost, schedule and the hierarchical relationships for the maintenance and operational support of U.S. CMS are defined in the Work Breakdown Structure. Detailed cost estimates have been developed using appropriate standard estimating methodologies, and integrated with the work scope definition. Schedules and plans have been developed using an approach that integrates the work scope with the cost estimate. Resources defined in the detailed estimate are applied to the tasks established in the schedule to generate a time-phased budget. All U.S. operational support is developed in close collaboration with the CMS Collaboration, and is in conformance with the goals of the CMS experiment.

It is anticipated that pre-operations and operations support of U.S. CMS will require an annual review to optimize out-year baseline budgets and the use of management reserve. The review will be organized by the RPM as part of the input required to apportion of funds between the M&O and SWC components of the RP.

7.2 OPERATIONS PERFORMANCE

Operations performance integrates the work authorization with the funds management and accounting processes to provide a performance analysis capability for both the U.S. CMS Operations management and the DOE/NSF.

Funds management is based on funds authorized by both the DOE and NSF that are allocated to the individual institutions in accordance with the need of U.S. CMS operations. Work authorization is provided for each institution through the U.S. Institutional MOU process that defines the full work scope, and establishes the fiscal year funding. Standard accounting

processes are used to collect actual costs for completed work and to define the funds available for the remainder of the fiscal year.

A status report will be issued each quarter (month ending March, June, September, and December) that contains the following information:

- A narrative describing the status of technical work, significant accomplishments, problems and corrective action if applicable.
- Actual costs accrued to U.S. CMS Operations organized by WBS number and compared to budgeted amounts.
- Schedule performance against planned milestones.
- Management reserves and future planned demands on reserve funds.

8 SUPPORTING FUNCTIONS

8.1 QUALITY ASSURANCE

CMS Management has established a Quality Assurance Plan (QAP) at CERN to assure that the detector systems will achieve the technical requirements and reliability needed for operation at the LHC. This assigns overall responsibility to the CMS Spokesperson, assisted by the Technical Coordinator.

Quality Assurance is an integral part of the design, procurement, fabrication, assembly and test of all the systems that are part of the U.S. CMS Operations. The U.S. CMS Operations Manager has the overall responsibility for quality assurance. In general, the U.S. CMS Subsystem Managers have the quality assurance responsibilities for their subsystems including the following aspects of quality control:

- Identification of those areas, concepts and components that require in-depth studies, prototyping and testing.
- Incorporation of necessary acceptance tests into plans and specifications.
- Verification of system performance requirements.
- Documentation of procedures and test results for the fabrication and procurement phase.

8.2 ENVIRONMENTAL SAFETY & HEALTH

The overall CMS Management has established an ES&H program at CERN to assure that the detector systems conform to the safety standards in force CERN at the time of delivery to CERN. Again, the U.S. CMS Operations Manager has the overall responsibility for ensuring that the systems comprising part of the U.S. CMS pre-operations and operations satisfy all relevant CMS-specified safety regulations and that all institutional ES&H requirements are fully met for U.S. CMS work performed in those institutions. In general, the U.S. CMS Subsystem Managers have responsibility for ES&H issues within their own subsystems including the following:

- Reviewing designs, procedures and practices to identify ES&H potential hazard considerations and ensure that potential hazards are adequately addressed.
- Assuring that ES&H requirements are met and procedures are followed correctly during operations and maintenance activities.

8.3 PROPERTY MANAGEMENT

All property will be managed in accordance with established practices of the participating U.S. CMS institutions. Property transferred to CERN will be subject to the provision of the International Agreement.

9 REVIEW AND MODIFICATION OF THE OPERATIONS MANAGEMENT PLAN

After its adoption, this Operations Management Plan is periodically reviewed by the Operations Manager and the Subsystem Managers as part of the preparation for reviews by the OMG. The US CMS Operations Manager, the U.S. CMS Research Program Manager, the FNAL Deputy Laboratory Director, or the funding agencies may initiate proposals for its modification.

The present OMP is viewed as the tool needed to move the U.S. CMS Collaboration through the end of construction, the pre-operations phase, and into operations. It is likely, however, that the OMP may undergo meaningful changes, due to the length of time prior to entering into a steady state operations phase, uncertainties in the relationships to the U.S. HEP base program support, the U.S. Software and Computing Operations, and the LHC Research Program itself.

Modifications of the Operations Management Plan will require approval of the OPM, the DRPM, the RPM, the Deputy Laboratory Director, the DOE/NSF Program Manager, and the Joint Oversight Group.

10

REFERENCES

1. DOE/NSF MoU Between DOE and NSF concerning U.S. Participation in the LHC Program, December, 1999.
2. Letter, JOG to FNAL Director; Host Laboratory Role for the U.S.CMS Research Program; Nov. 21, 2000.
3. Letter, Director, DOE Division of High Energy Physics to U.S. CMS, U.S. ATLAS Project Managers; subj: U.S. LHC Pre-Operations Funding Profiles; March 8, 2002.
4. U.S. LHC Construction Project Execution Plan, Rev. 1, October, 2002.
5. Letter, JOG to U.S. CMS , U.S. ATLAS Project Managers; re: U.S. LHC Pre-Operations & Operations; March 7, 2002.
6. Letter, JOG to U.S. LHC Detector Maintenance & Operations Evaluation Group members; subj: .S. LHC Detector Maintenance & Operations Evaluation Group; date: March 5, 2003.
7. Letter, JOG to: FNAL Director; re: U.S. CMS Program Management; date: November 7, 2003.

LIST OF ABBREVIATIONS

AB	U.S. CMS Collaboration Advisory Board
AY	At Year (referring to a dollar value)
CB	CMS Collaboration Board
CERN	European Laboratory for Particle Physics
CH	DOE Chicago Operations Office
CR	Change Requests
DOE	U.S. Department of Energy
DRPM	Deputy Research Program Manager
ES&H	Environmental Safety and Health
FSO	Fermi Site Office
IB	U.S. CMS Collaboration Institutional Board
JOG	Joint Oversight Group
LHC	Large Hadron Collider
LHCC	CERN LHC Committee
MB	CMS Management Board
MOU	Memorandum of Understanding
M&O	Maintenance and Operations
NSF	National Science Foundation
OMG	Operations Management Group
OPM	U.S. CMS Operations Program Manager
OMP	Operations Management Plan
PEP	U.S. LHC Project Execution Plan
R&D	Research and Development
RPM	U.S. CMS Research Program Manager
RRB	CMS Resource Review Board
SC	Steering Committee
SM	U.S. CMS Subsystem Manager
WBS	Work Breakdown Structure

APPENDIX 1. HOST LAB LETTER

JOINT OVERSIGHT GROUP

Dr. Michael Witherell
Director
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, IL 60510

Dear Dr. Witherell:

The U.S. Department of Energy (DOE) and the National Science Foundation (NSF) are supporting construction of the Large Hadron Collider (LHC) at the European Center for Particle Physics (CERN) under the terms of the International Agreement between CERN and the U.S. with its protocols, and the interagency Memorandum of Understanding of December, 1999. Under that Agreement, the U.S. Compact Muon Solenoid (CMS) Construction Project has been managed by Fermilab as Host Laboratory. Fermilab, as the Host Laboratory, has provided the central management to oversee and coordinate project activities and reporting, in addition to providing specific elements of the project as a collaborating institution.

The International Agreement provides that, beyond the LHC Construction Project, U.S. scientists will participate as full partners in the LHC Research Program. The DOE and the NSF are now considering the elements necessary for successful U.S. participation in the Research Program, including both the pre-operational and operational phases. The first elements of that participation are in place, namely the designation of Brookhaven National Laboratory (BNL) and Fermi National Accelerator Laboratory (FNAL) as Host Laboratories, respectively, for the U.S. ATLAS and U.S. CMS Research Programs. The Host Laboratories, with the U.S. collaborations, have already made substantial progress in organizing and implementing the U.S. LHC Software and Computing Project. In particular, the management structures are in place, Project Management Plans have been drafted, and software development and Tier 1 computing centers have been initiated. A baseline review of the Project is scheduled for November 2000.

Another major component of the U.S. LHC Research Program, pre-operational and operational support of the U.S. participation in the ATLAS and CMS detectors beyond base support, must now be put in place. You have agreed to be Host Laboratory for the U.S. CMS Research Program. In that capacity, we now request that you initiate planning and assume management oversight for the pre-operational and operational phases of the U.S. CMS Research Program. This management oversight includes the development of annual budget requests, and the preparation, in concert with the U.S. CMS Collaboration, of a Management Plan for Pre-operations and Operations. The draft Plan should be submitted to the DOE/NSF Joint Oversight Group for approval.

The planning, to be developed with the appropriate leadership at CERN, could be expected to include:

Participation in detector operations and data monitoring;

Support for monitoring and maintenance of U.S.-provided subsystems;

Establishment of an environment at Fermilab including a virtual control room to facilitate U.S.-based physics analysis; and,

Continuing R&D, with possible fabrication, of upgrades to enhance the physics productivity of the detector.

This document further specifies the responsibilities agreed upon in the Host Laboratory letter of August 1999. Funding will be identified to carry out the U.S. CMS Research Program, including both Software and Computing, and Pre-operations and Operations. We expect that the methods for allocating the designated funding within the Research Program will be similar to those used for the U.S. CMS Construction Project. The methods of allocation should be specified in the Project Management Plan.

Sincerely,

John R. O'Fallon
Co-chair
U.S. LHC Joint Oversight Group
Department of Energy

John W. Lightbody, Jr.
Co-chair
U.S. LHC Joint Oversight Group
National Science Foundation

On behalf of Fermilab, I accept this further specification of the Host Laboratory role for the U.S. CMS Research Program.

Dr. Michael Witherell
Director
Fermi National Accelerator Laboratory

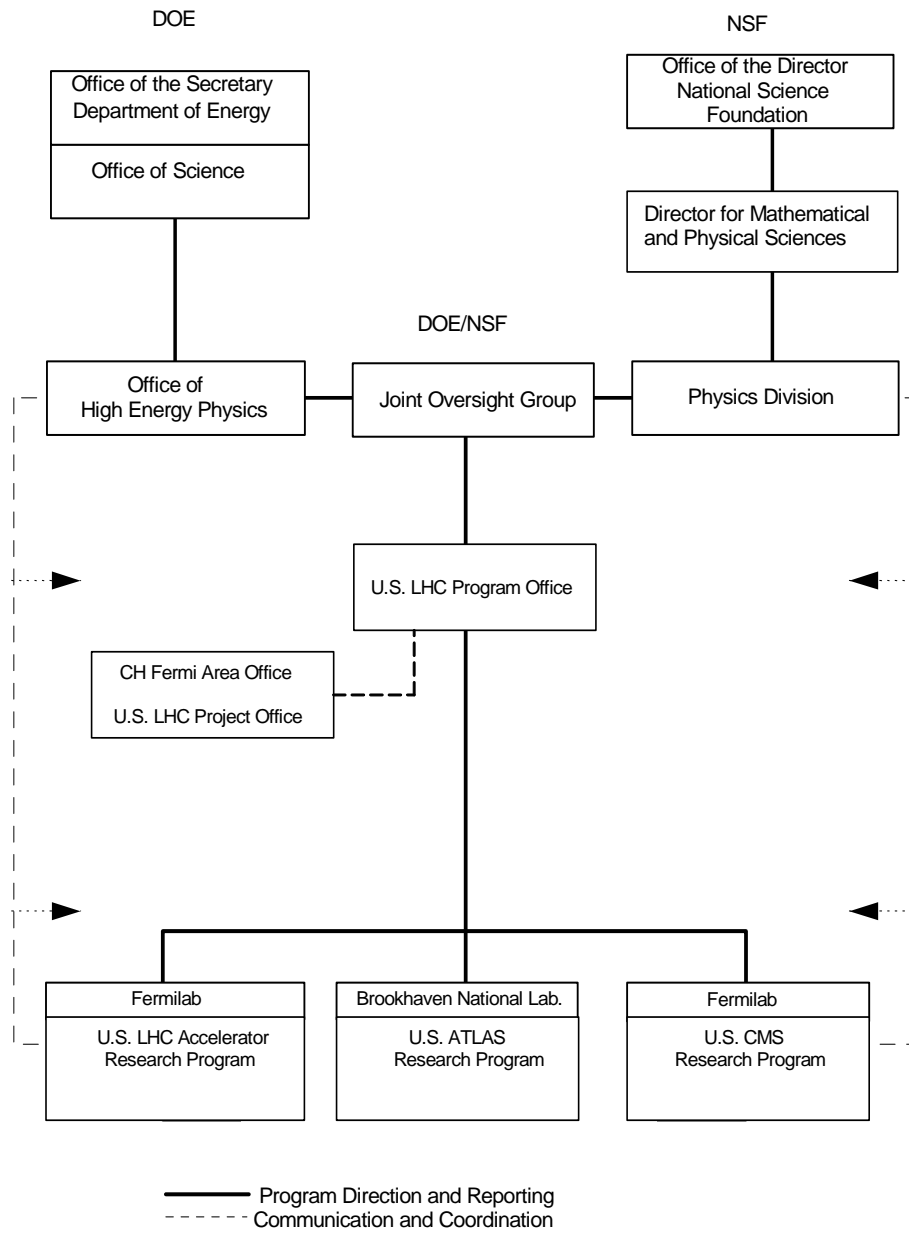
cc:

Michel Della Negra, CERN
Mildred Dresselhaus, SC-1
Robert Eisenstein, NSF
Marvin Goldberg, NSF
Daniel Green, FNAL
Matthias Kasemann, FNAL

Jane Monhart, CH/Fermi
Harvey Newman, CalTech
S. Peter Rosen, SC-20
Kenneth Stanfield, FNAL
Timothy Toohig, SC-223
Jim Yeck, CH/Fermi

APPENDIX 2. DOE-NSF-U.S. CMS ORGANIZATION

U.S. LHC Research Program Management Organization

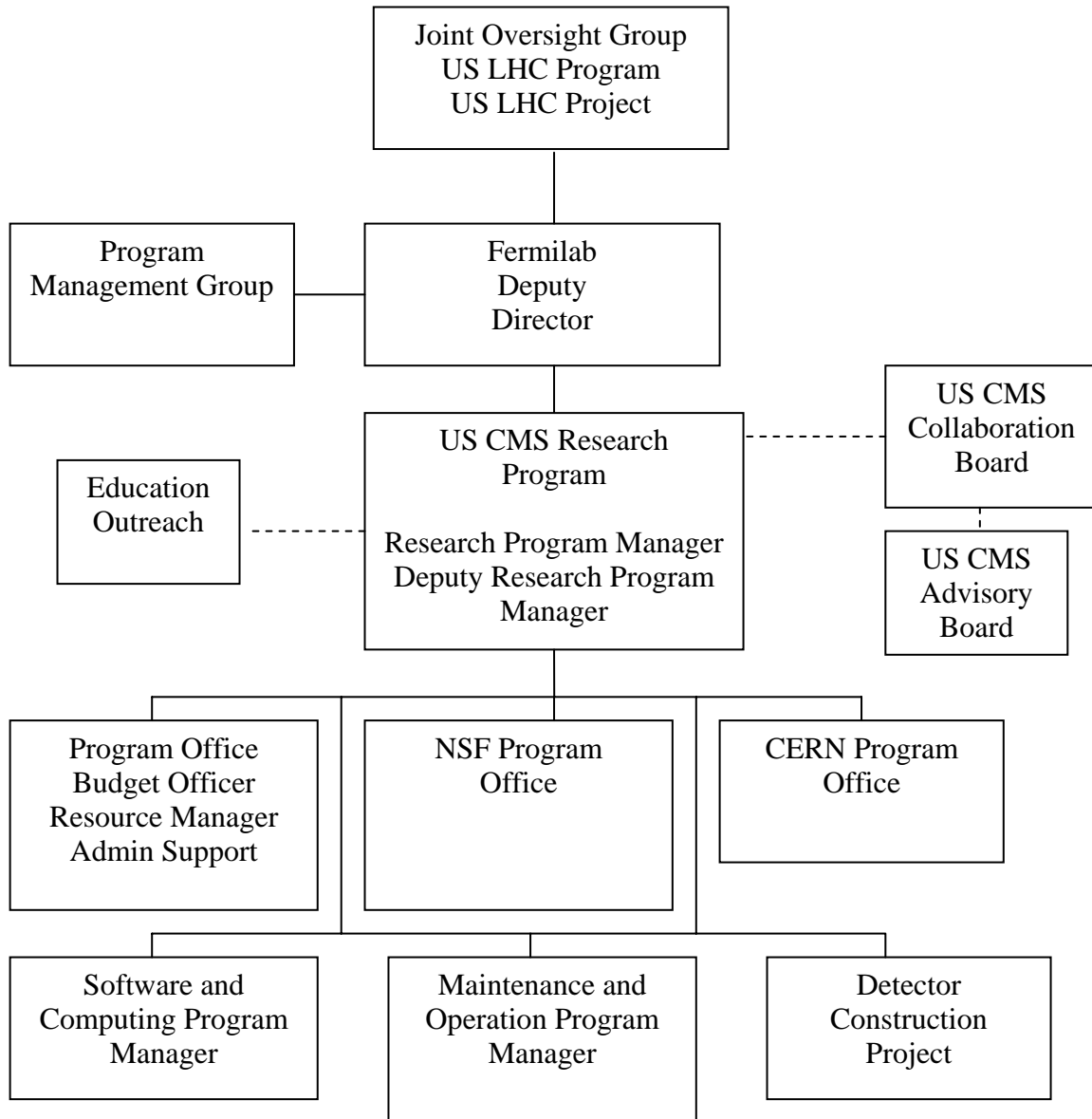


APPENDIX 3. U.S. PARTICIPATING INSTITUTIONS

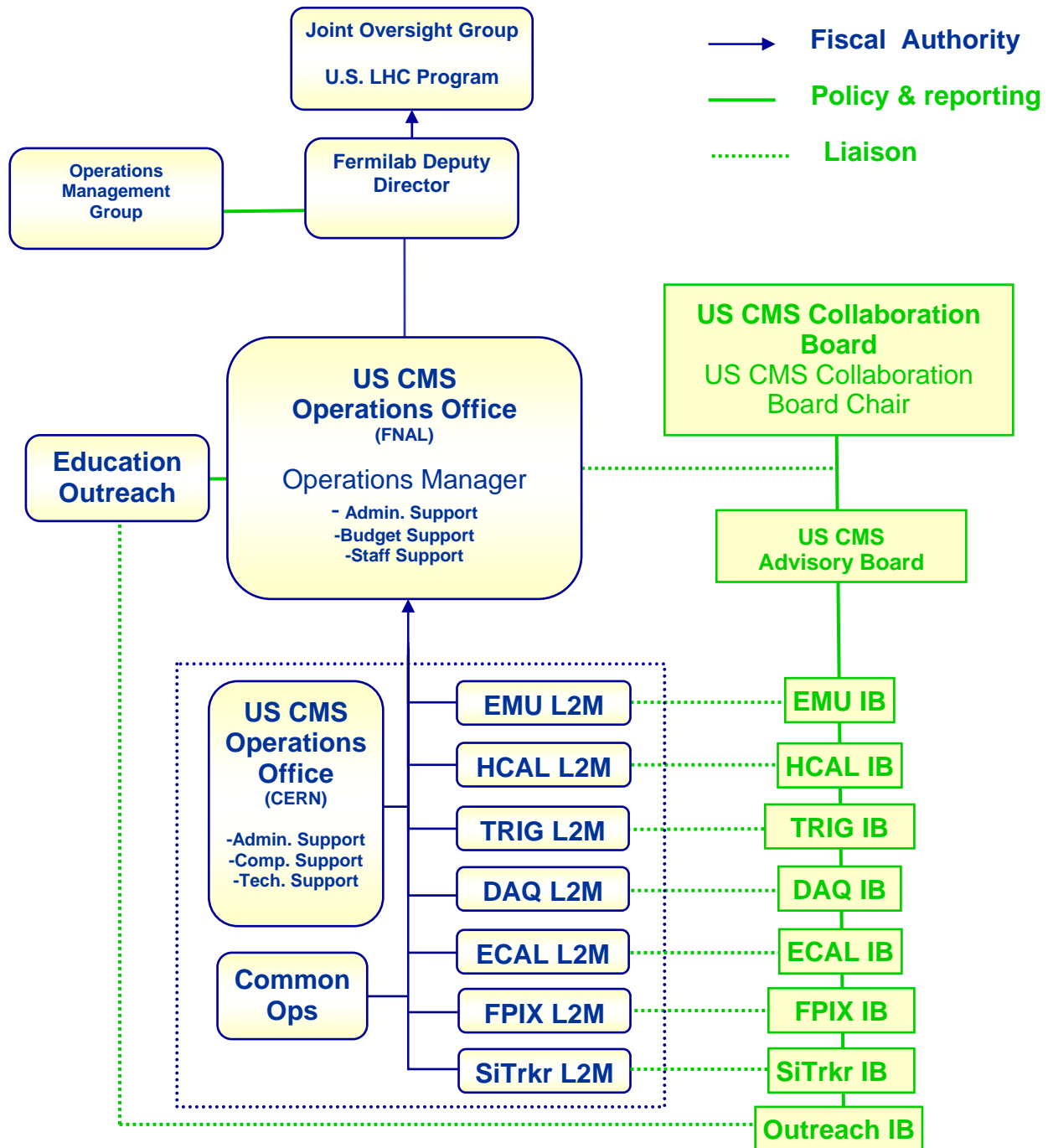
Institution	Agency Support
Boston University	DOE
Brown University	DOE
University of California at Davis	DOE
University of California at Los Angeles	DOE/NSF
University of California at Riverside	DOE
University of California at San Diego	DOE/NSF
University of California at Santa Barbara	DOE
California Institute of Technology	DOE
Carnegie Mellon University	DOE
Fairfield University	DOE
Fermi National Accelerator Laboratory*	DOE
University of Florida	DOE
Florida Institute of Technology	DOE
Florida International University	NSF
Florida State University	DOE
University of Illinois at Chicago	NSF
University of Iowa	DOE
Iowa State University	DOE
Johns Hopkins University	NSF
University of Kansas	NSF
Kansas State University	DOE
University of Maryland	DOE
Massachusetts Institute of Technology	DOE
University of Minnesota	DOE
University of Mississippi	DOE
University of Nebraska	DOE
Northeastern University	NSF
Northwestern University	DOE
University of Notre Dame	NSF
Ohio State University	DOE
Princeton University	DOE
Purdue University	DOE
Rice University	DOE
Rutgers University	NSF
University of Rochester	DOE
Texas Tech University	DOE
Virginia Technical Institute	NSF
University of Wisconsin, Madison	DOE
Yale University	DOE

* Designated as Host Laboratory for U.S. CMS Operations

APPENDIX 4. U.S. CMS RESEARCH PROGRAM ORGANIZATION



APPENDIX 5. U.S. CMS OPERATIONS ORGANIZATION

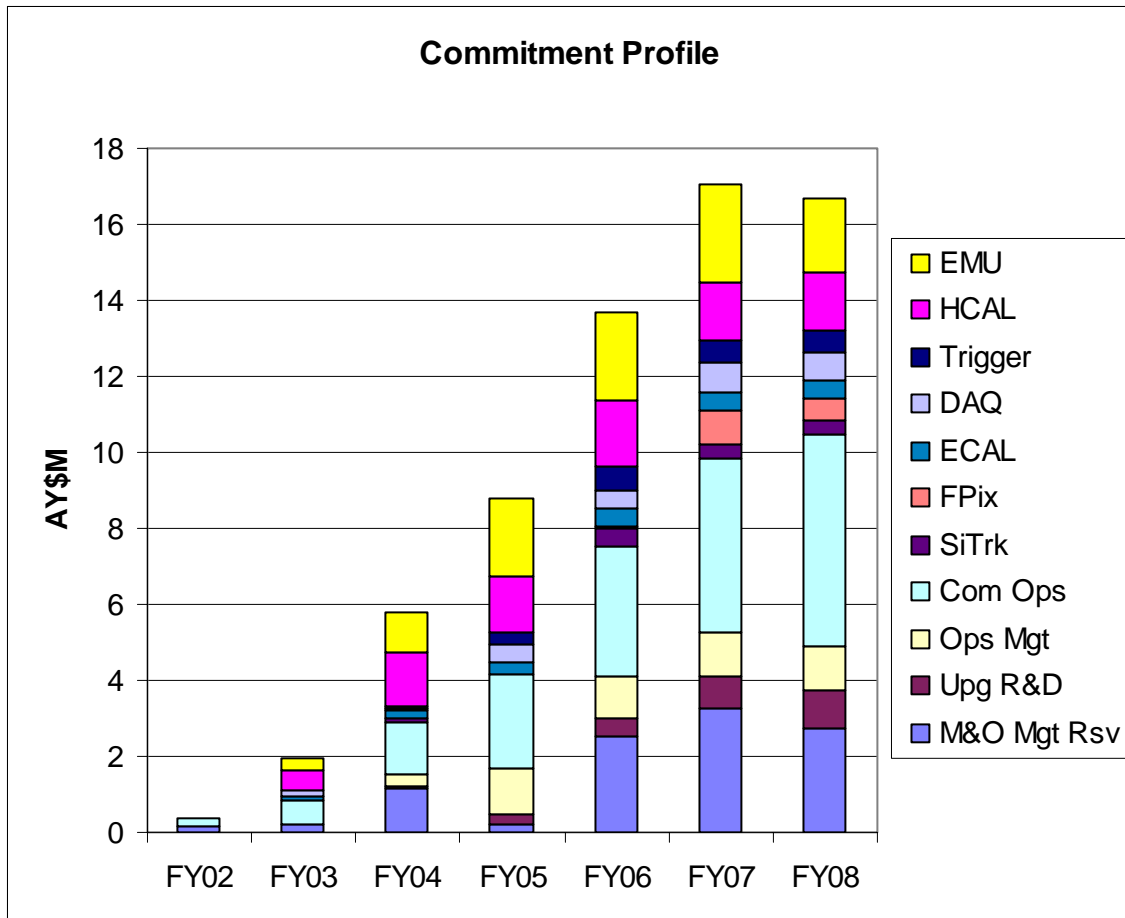


APPENDIX 6. U.S. CMS OPERATIONS WBS

WBS	Name	Start	2001	2002	2003	2004	2005	2006	2007	2008
	<input type="checkbox"/> US CMS Pre-Operations and Operations	Oct 1 '01								
11	Endcap Muon M&O	Oct 1 '01								
12	Hadron Calorimeter M&O	Oct 1 '01								
13	Trigger M&O	Oct 1 '04								
14	Data Acquisition M&O	Oct 1 '02								
15	Electro-Magnetic Calorimeter M&O	Jun 3 '02								
16	Forward Pixels M&O	Oct 1 '03								
17	Silicon Tracker M&O	Oct 3 '05								
18	Common Operations M&O	Oct 1 '01								
19	Operations Management	Oct 1 '01								
20	Upgrade R&D	Oct 1 '01								
21	Management Reserve	Oct 1 '01								

APPENDIX 7. U.S. CMS OPERATIONS COST ESTIMATE AND PROFILE

(AYK\$)



APPENDIX 8. U.S. CMS DETECTOR INSTITUTIONAL RESPONSIBILITY BY SUBSYSTEM

Subsystem	WBS	IB Representative	Institutions
Endcap Muon	11		UC-Davis, UC-Los Angeles, UC-Riverside, Carnegie Mellon, Florida Institute of Technology, FNAL, Florida, Northeastern, Ohio State, Purdue, Rice, Wisconsin
Hadron Calorimeter	12		Boston, Fairfield, FNAL, Florida Institute of Technology, Florida International University, Florida State, Illinois-Chicago, Iowa, Iowa State, Maryland, Minnesota, Mississippi, Nebraska, NEU, Notre Dame, Princeton, Purdue, Rochester, Texas Tech
Trigger	13		UC-Los Angeles, Florida, Rice, Wisconsin
Data Aquisition	14		UC-Los Angeles, UC-San Diego, FNAL, MIT
Electromagnetic Calorimeter	15		Caltech, Minnesota, Northeastern, Princeton, Yale
Forward Pixels	16		UC-Davis, FNAL, Johns Hopkins, Mississippi, Northwestern, Purdue, Rutgers
Silicon Tracker	17		UC-Riverside, UC-Santa Barbara, FNAL, Kansas, Kansas State, Northwestern, Rochester, Illinois-Chicago
Common Operations	18		FNAL, UCLA, Notre Dame
Operations Management	19		FNAL, UCLA

[illegible]